VII. *Experiments and Observations, made with the View of ascertaining the Nature of the Gaz produced by passing Electric Discharges through Water. By* George Pearson, *M. D. F. R. S.*

Read February 2, 1797.

§ 1.

In the *Journal de Physique* for the month of November, 1789, were published the very curious and interesting experiments of Messrs. Paets van Troostwyk and Deiman; which were made with the assistance of Mr. Cuthbertson; on the apparent decomposition of water by electric discharges.

The apparatus employed was a tube 12 inches in length, and its bore was $\frac{1}{8}$ of an inch in diameter, English measure; which was hermetically sealed at one end, but before it was sealed, $1\frac{1}{2}$ inch of gold or platina wire was introduced within the tube, and fixed into the closed end by melting the glass around the extremity of the wire. Another wire of platina, or of gold with platina wire at its extremity, immersed in quicksilver, was introduced at the open end of the tube, which extended to within $\frac{5}{8}$ of an inch of the upper wire, which, as was just said, was fixed into the sealed extremity.

The tube was filled with distilled water, which had been freed from air by means of Cuthbertson's last improved air pump, of the greatest rarefying power. As the open end of the tube was immersed in quicksilver, a little common air was

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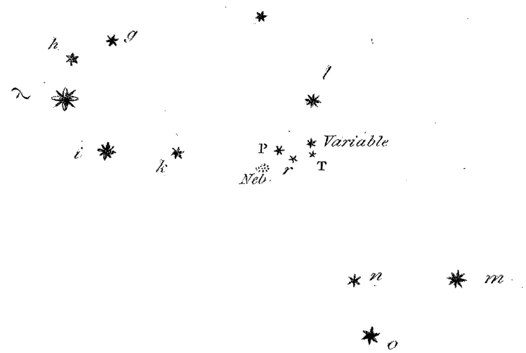

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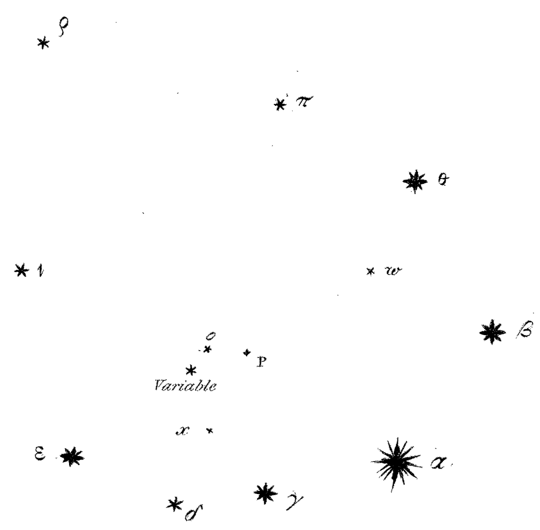

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let up into the convex part of the curved end of the tube, with the view of preventing fracture from the electrical discharge.

The wire which passed through the sealed extremity was set in contact with a brass insulated ball; and this insulated ball was placed at a little distance from the prime conductor of the electrical machine. The wire of the lower or open extremity, immersed in quicksilver, communicated by a wire or chain with the exterior coated surface of a Leyden jar, which contained about a square foot of coating; and the ball of the jar was in contact with the prime conductor.

The electrical machine consisted of two plates of 31 inches in diameter, and was similar to that of TEYLER. It had the power of causing the jar to discharge itself 25 times in 15 revolutions. When the brass ball and that of the prime conductor were in contact, no air or gaz was disengaged from the water by the electrical discharges; but on gradually increasing their distance from one another, the position was found in which gaz was disengaged; and which ascended immediately to the top of the tube. By continuing the discharges, gaz was discharged till it reached to nearly the lower extremity of the upper wire, and then a discharge occasioned the whole of the gaz to disappear, a small portion excepted, and its place was consequently supplied by water.

From my own experience I should venture to affirm, that a more particular and more accurate account than that published is requisite, to enable the student, or even the proficient, to institute the above experiment with success. Hence, during the six or seven years which have elapsed since its publication, no confirmation has been published, except the experiment repeated by Mr. CUTHBERTSON for my satisfaction, as related in

my work on the Chemical Nomenclature; although I have heard of many persons, and some of them experienced electricians and chemists, who have made the attempt. But by labouring with Mr. CUTHBERTSON, since he came to reside in London, I have learned the circumstances on which the success of the experiment depends; and I have received from him effectual aid in continuing a process, with the objects I had in view, the tediousness and even difficulties of which can only be conceived by those who have been engaged in the same pursuit.

In the course of my experiments on this subject, Mr. CUTHBERTSON invented a new method of disengaging gaz from water, by means of the electrical discharges, namely, by means of *uninterrupted* or *complete discharges;* whereas the method of Mr. VAN TROOSTWYK was by *interrupted discharges.* The *rationale* of the process according to these two methods, I apprehend, cannot be understood without an explanation; for I find books on electricity do not contain the necessary information.

In the experiment of Mr. VAN TROOSTWYK, it must be considered, that if in place of water the tubes be filled with air, the whole of the charge of the Leyden jar will pass, at each explosion, from the upper to the under wire, and no interruption in the discharge will happen; but if they are filled with water, then an *interrupted discharge* may be caused: by which is meant, that a part of the charge only passes at each explosion through the water from wire to wire, and with much diminished velocity. The residuary electricity in the Leyden jar is nearly one half, as may be accurately demonstrated. The reason of these differences must be assigned from the difference in point of density, elasticity, and conducting power, of the medium of

water and of air. It must be added, that although water in large quantity is a good conductor, and air is not, yet water being here in very small quantity it proves a bad conductor; as is the case with the very best conductors. A cubic foot of water is only just capable of receiving, or letting pass through it, a full discharge from a jar of one foot of coated surface; and the quantity of water employed in this experiment not being $\frac{1}{100,000}$ part of a cubic foot it is a very imperfect conductor; so that an interrupted discharge only can pass through the tube, without dispersing the whole of the water. But if the discharge be not seemingly as strong as the tube can bear without breaking, the gaz is not produced from it; and on this point hinges this extremely delicate process.

The situation of the different parts of the apparatus for the interrupted discharge is shewn by Tab. III. fig. 5.

To succeed by the method of the *complete* or *uninterrupted discharge*, the apparatus now to be described must be used, and the following rules must be observed.

1. A tube, fig. *6*. is employed, about four or five inches in length, and its bore one-fifth or one-sixth of an inch in diameter. One end is mounted with a brass tube, fig. 7. and the other end is sealed at the lamp with a wire, about $\frac{1}{40}$ of an inch in thickness, fixed into it, as above described; which extends into the brass tube, so as to be almost in contact where the explosion is made. If the wire touches the brass tube, there will be no gaz produced. The tube being filled with water, and set in a cup of water, the discharge may be made into it, as in the above described process of Mr. VAN TROOSTWYK; but here the insulated ball must be placed at a greater distance from the prime conductor, and a Leyden jar with only fifty square inches of coating

will answer the purpose. In this way of making the experiment gaz is produced by each discharge, in the brass tube; and in much greater quantity, and with much less frequent accidents, and less trouble, than in the former method with the interrupted discharge. But the gaz obtained with this apparatus always contains a large proportion of atmospherical air, on account of the quantity of water and more immediate and extensive communication of it with the atmosphere. By repeated discharges there is an impression made in the brass tube, in the part where the discharge passes through it, and at last a small hole is made in that part. On this account the same mounted tube cannot serve for producing a large quantity of gaz.

2. The other sort of apparatus, invented by Mr. CUTHBERTSON, is represented by fig. 8. At first it consisted of a glass tube half an inch wide, and about five inches in length, mounted at one end with a brass funnel, and inverted in a brass dish; but afterwards the tube was blown funnel-wise at the end, as shewn by fig. 9. The other end must have a wire, about $\frac{1}{40}$ of an inch thick, sealed into it at the lamp; which wire extends to nearly the bottom of the brass dish in which the tube stands.

The exact distance between the end of the wire and brass dish must be found by trials; that which generally answered in my experiments was about $\frac{1}{20}$ of an inch. If it be properly arranged, gaz will be produced at each discharge.

The Leyden jar used with this apparatus, must contain about 150 square inches of coating.

The distance between the insulated ball and the prime conductor, at which the experiment succeeded, was commonly about half an inch.

If experiments be proposed, in which electric discharges must

be passed through water, or other fluids, for even a much longer time than was consumed in performing those referred to, or related in this paper; it may be an object to employ the wind, or perhaps the power of a horse, to turn the electrical machines; the expence of labourers being considerable.

§ 2. Experiments.

From my journal of the numerous experiments, made during the course of nearly two years, I shall select those which will serve to explain the nature of the process, and show the power of the plate electrical machines; and I shall particularly relate those experiments which afforded the most useful results concerning the nature of the gaz obtained.

1. *With interrupted Discharges.*

Experiment A. About 1600 of these discharges, by means of a thirty-four inch single plate electrical machine, in nearly three hours, produced, from New River water taken from the cistern, and which had not been freed from air by the air pump or boiling, a column of gaz two-thirds of an inch in length and one-ninth of an inch wide. On passing through this gaz, between the two wires of the tube in which it was produced, a single electric spark, its bulk was instantly diminished to two-thirds. In other experiments the bulk of gaz was only diminished to about one half. And the result was the same with distilled water.

B. The experiment A being repeated several times, with distilled and New River water, freed from air by the air pump or long boiling, the quantity of gaz just mentioned was obtained in about four hours.

On passing an electric spark through this gaz, in the situation

above mentioned, its bulk was instantly diminished, in some cases $\frac{15}{16}$, and in others $\frac{19}{20}$.

C. 1600 interrupted discharges, by means of a thirty-two inch plate machine, produced, from New River water and distilled water freed from their air by the air pump, a column of gaz about three-fourths of an inch in length, and one-ninth of an inch in diameter, in the space of three hours. It was reduced in bulk $\frac{19}{20}$ by passing through it a single electric spark.

D. 500 revolutions of the thirty-two inch plate machine, in three quarters of an hour, produced 600 interrupted discharges in river water, freed from air by the air pump, by which a column of gaz, half an inch in length and one-tenth of an inch in diameter, was obtained. It was diminished, as usual, by an electric spark, $\frac{19}{20}$ of its bulk.

E. Nearly four days incessant labour, with the thirty-two inch plate machine, produced only 56,5488 cubes of gaz, of one-tenth of an inch each; on account of the usual accidents during the process. The air had been exhausted, by setting the water under the receiver of the air pump.

F. It was found that 6000 interrupted discharges produced about three inches in length of gaz, measured in a tube $\frac{3}{20}$ of an inch in width, from water out of which its air had been drawn by the air pump.

G. It appeared, from many experiments, that the same unboiled water, or water from which the air had not been exhausted by the air pump, which had repeatedly yielded gaz by passing through it electric discharges, always left a residue of gaz, which the electric spark did not diminish; and this residue was in nearly the same quantity, after six or seven experiments, each of which afforded a column of gaz, half an inch in length,

and one-ninth of an inch in diameter, as was left on passing the electric spark through the gaz, afforded by the third or fourth experiment.

Hence it seems, that water is decompounded by the electric discharge, before the whole of the common or atmospherical air is detached from the water, by merely the impulse of each discharge. Yet I think it probable that, after the discharges have been passed through the same water for a certain time, the whole of the air contained in water will be expelled, and no gaz be produced, but that compounded by means of the electric fire from water; in which case, supposing the gaz so produced to be at last merely hydrogen and oxygen gaz, it will totally disappear on passing through it an electric spark. But I have never been able to determine this point; because the tubes were always broken after obtaining a few products, or long before it could reasonably be supposed the whole of the air of the water was expelled from it.

H. To the gaz obtained in the experiment E was added, over water, an equal bulk of almost pure nitrous gaz. Fumes of nitrous acid appeared, and the gaz examined was reduced almost one-third of its bulk. A small bubble more of nitrous gaz being let up no further diminution took place. To this residue was added half its bulk of oxygen gaz, obtained from oxymuriate of potash. This mixture of gazes having stood several days over well burnt lime and boiled quicksilver, an electric spark was passed through the mixture, over quicksilver; by which its bulk was instantly diminished one-fourth. But no moisture could be perceived upon the sides of the tube, or on the quicksilver. The failure of the appearance of moisture was imputed to a bit of lime accidentally left in the tube,

which was burst by the explosion and dispersed through the tube; or else the quantity of water produced was so small, comparatively with the residuary gaz, that the water was dissolved by it in the moment of its composition. For supposing water to have been compounded, it could not amount to the $\frac{1}{100}$ part of a grain; and the residuary gaz was at least two thousand times this bulk.

That a quantity of water can be compounded, under the same circumstances as in this experiment, and be apparently dissolved in air, so as to escape observation, even with a lens, was proved by passing an electric spark through a mixture of hydrogen and oxygen gaz, well dried by standing over lime.

2. *With complete or uninterrupted Discharges.*

The gaz obtained by the first described kind of apparatus, for the uninterrupted discharges, p. 145, and fig. 6 and 7, always left a residue of at least one-fourth of its bulk on passing through it the electric spark; even when water was used, which had been freed from air by boiling, or the air pump. Nor will this result appear surprising, when it is considered how liable the water in this apparatus is to mix and absorb air during the experiment. However, this method would have been extremely valuable if the next other method had not been discovered; for gaz may be obtained by it with fewer accidents, and much more rapidly, than with the interrupted discharges. The apparatus is also much more easily fitted up, and is more simple. But I think it unnecessary to particularly relate any experiments, as they afforded the same results as those already described, and as those next to be related.

The following experiments were made with the apparatus described p. 146, and shown by fig. 8, 9, and 10.

Experiment 1. At 0^h $40'$ P. M. began to produce discharges with a double plate twenty-four inch machine, in water taken from the cistern: and at 12^h $6'$ P. M. of the same day there had been written down 10200 discharges, each of which occasioned air to ascend from the bottom of the wire and brass cup. The quantity of air obtained was now apparently about one-fourth of a cubical inch, and it occupied nearly half of the tube; the water in which was by this time very muddy.

After standing till the day following at noon, when the process was again commenced, it did not appear that any of the gaz had been absorbed by the water over which it stood.

At 2^h $35'$ P. M. began to produce discharges, and at 8^h P. M. had passed 6636; which, together with those of the preceding day, amounted to 16836. The tube was now $\frac{5}{8}$ full of gaz, and there seemed to be almost half a cubical inch; for it was observed, that the gaz was this day yielded at double the rate it had been the day before. This was accounted for from the diminished pressure upon the electric fire, by the tube containing gaz instead of water.

At this time, namely, at 8^h P. M. I was surprised, on the passing of a discharge, by a vivid illumination of the whole tube, and a violent commotion within it; with, at the same time, the rushing up of water, instantly to occupy rather more than $\frac{5}{8}$ of the space which had been occupied by gaz.

The residue of gaz was not diminished further by an electric spark; and to the test of nitrous gaz it appeared to be rather worse than atmospherical air, as it consisted of rather less than one part of oxygen, and three parts of nitrogen or azotic gaz.

It seemed as if the electrical discharge had kindled the oxygen and hydrogen gaz of the decompounded water, by flying from the bottom of the wire to the brass funnel; so that the fire returned into the tube where it passed through the gaz. Or the combustion might be occasioned by a chain of bubbles, reaching from the brass dish to the surface of the water in the tube, which was set on fire in its ascent, and thus produced combustion of the whole of the gaz of decompounded water.

That this phænomenon was from the combustion here supposed, was in some degree proved by finding that the mixture of hydrogen gaz and atmospherical air, under the same circumstances, was kindled in the same manner.

Experiment II. With a double plate electrical machine, 24 inches in diameter, and a similar apparatus to that in the last experiment, 14600 discharges produced, at least, one-third of a cubical inch of gaz. While I was measuring with a pair of compasses the quantity of gaz produced, the points of them being in contact with the part of the tube occupied by gaz, I was again surprised, on the passing of a discharge, by an illumination of the whole tube, and the rushing up, with considerable commotion, of water, to occupy about two-thirds of the space filled by gaz.

The residuary air was found, as in the former experiment, to be rather worse than atmospherical air.

It was concluded that the points of the compasses had attracted electrical fire from the wire to the sides of the glass, and thereby kindled the hydrogen and oxygen gaz of decompounded water. But to determine this question, I introduced into the same tube a mixture of one measure of oxygen and two measures of hydrogen gaz, to occupy nearly the same

space in the tube as the gaz had occupied: then passing an electrical discharge through it no combustion was excited; but on passing a discharge while the compasses were in contact with the tube, as just mentioned, an illumination and violent commotion were produced, with the rushing up of water, to leave only $\frac{1}{8}$ of the gaz as a residue. On repeating this experiment with one measure of atmospherical air and two of hydrogen gaz, combustion could not be excited; nor with two measures of atmospherical air and one of hydrogen; nor with two measures of hydrogen gaz and one of atmospherical air; but on adding to this last mixture one measure of oxygen gaz, the electrical discharge produced the phænomena of combustion just mentioned, with the rushing up of water, to occupy about two-thirds of the space which was occupied by the gazes.

Experiment III. Having passed 12000 discharges through water, with the apparatus of the preceding experiment, and thereby obtained only one-fifth of a cubical inch of gaz; and having observed, that the quantity of gaz was not greater than it was when only 8000 discharges had been passed, and yet bubbles had been seen to be produced on each discharge as copiously, or more so, by the last 3 or 4000 discharges as before; I began to suspect that part of the gaz had been destroyed during the process, or had been absorbed. While I was considering how to account for this disappearance of gaz, and was at the same time looking at the tube through which the discharges were passing, I observed one of them to be atended with a diminution, instantly, of about one-fifth of the gaz produced, and with a slight commotion. I was now sure, from this phænomenon, and from the unequal augmentation of the bulk of the gaz at given

times during the process, that combustion had been excited several times before; not only in the present experiment, but perhaps in the former ones, without observing it. I conceived that a gradual combustion also, very probably, took place in this process, by the kindling of bubbles of gaz in their ascent through the water. I now perceived that the discharges ought to be produced more slowly, or the tubes to be wider, to allow the bubbles to pass quite through the water, in order to avoid the accension of gaz during the process. My calculation also, that 35 to 40000 discharges were requisite to produce one cubical inch of gaz from water, containing its usual quantity of common air, was rendered much more vague by this accension, so often liable to be occasioned.

To the gaz which remained in the tube in this experiment was added an equal bulk of nitrous gaz; the mixture diminished to 1,5; and on adding to the residue half its bulk of oxygen gaz, and passing through it the electrical spark, no accension or diminution of bulk was produced. Hence all the hydrogen gaz and oxygen gaz, produced by the decomposition of the water, had been burnt during the process; the oxygen gaz thus detected being considered to be only that expelled from the water.

Experiment IV. By means of electrical discharges, with the apparatus used in the preceding experiment, I obtained gaz from New River water; letting it up into a reservoir as soon as about $\frac{1}{20}$ of a cubic inch was produced, till I had collected $\frac{1}{8}$ of a cubic inch. To this was added an equal bulk of nitrous gaz; on which the mixture diminished to 1,2; and on the addition of a little more nitrous gaz, no further diminution took place. To this residue half its bulk of oxygen

gaz was added, and this mixture of gazes being well dried by standing over lime and boiled quicksilver, an electric spark was passed through it, by which a diminution of $\frac{1}{6}$ of its bulk took place. A little dew was then seen upon the sides of the tube where the quicksilver had risen; and, with the aid of a lens, the same appearance was perceived on the part of the tube containing the residue of gaz.

It may now be expected, that I should have made the experiments with this apparatus on distilled water freed from its air, not only by long boiling, or the air pump, but by passing through it several hundred electrical discharges. It would also have been, to some persons, more satisfactory, if the experiments had been made upon a larger scale, so as to have produced the combustion of a much larger quantity of gaz, and consequently have produced a greater quantity of water. As, however, I apprehend, the experiments contained in this paper, when well considered, by competent judges, will be found to explain the nature of the gaz procured from water by electrical discharges; and as another very important subject demands my attention, the honour of more splendid and convincing experiments must be reserved for other inquirers. If the same sacrifices be made by them, which have been made in performing the present experiments, I think it is scarcely possible but that still further light concerning the composition of water should be obtained, as well as concerning oils, alcohol, acids, &c.; to the investigation of the composition of which, the mode of analysis and synthesis here indicated, may be applied.

§ 3.

The following conclusions appear to me obvious and incontrovertible.

The mere concussion by the electric discharges seems to extricate not only the air dissolved in water, which can be separated from it by boiling and the air pump, but also that which remains in water, notwithstanding these means of extricating it have been employed.

The quantity of this air varies in the same and in different waters, according to circumstances. New River water from the cistern yielded one-fifth of its bulk of air, when placed under the receiver of Mr. CUTHBERTSON'S most powerful air pump; but, in the same situation, New River water taken from a tub exposed to the atmosphere for a long time yielded its own bulk of air. Hence the gaz produced by the first one, two, or even three hundred explosions in water, containing its natural quantity of air, is diminished very little by an electrical spark.

The gaz or air, thus separable from water, like atmospherical air, consists of oxygen and nitrogen or azotic gaz; which may be in exactly the same proportions as in atmospherical air, for the water may retain one kind of gaz more tenaciously than the other; and on this account the air separated may be better or worse than atmospherical air, in different periods of the process for extricating it.

The nature of the gaz, which instantly disappears on passing through it an electric spark, is shown by

(*a*) This very property of thus diminishing; and by the following properties;

(*b*) A certain quantity of nitrous gaz instantly disappeared, apparently composing nitrous acid, on being added to the gaz (*a*) p. 149, H. 154, Exp. IV.; oxygen gaz being added to the residue after saturation with nitrous gaz, and an electric spark being applied to the mixture of gazes, well dried, a considerable diminution immediately took place, and water was produced; p. 154, Exp. IV.

(*c*) Combustion from hydrogen and oxygen gaz took place, when the tube was about three-fourths full of gaz, p. 152, Exp. I. which was confirmed by passing an electrical discharge, under the same circumstances, through a mixture of hydrogen and oxygen gaz, p. 152, Exp. I.

(*d*) Combustion from hydrogen and oxygen gaz took place, when the points of the compasses were accidentally applied to the part of the tube containing gaz, p. 152, Exp. II.; which was confirmed by passing a discharge, under the same circumstances, through a mixture of hydrogen and oxygen gaz, while the points of the compasses were applied to the tube; p. 153, Exp. II.

(*e*) The observations made of the kindling of gaz in small quantities, from time to time, during the process of obtaining it, particularly while it was ascending in chains of bubbles, or was adhering to the funnel of the tube, p. 153, 154, Exp. III. confirm the evidence in favour of this gaz being hydrogen and oxygen gaz.

The evidence contained under the heads (*a*)—(*e*), considered singly and conjunctively, I apprehend, must be admitted

by the most rigorous reasoner, to be demonstrative that hydrogen and oxygen gaz were produced by passing electric discharges through water.

With regard to the origin and mode of production of these two gazes, our present observations and experiments do not afford complete demonstrative evidence; but, although some hypotheses must be admitted, I conceive that the body of evidence we possess can afford a satisfactory interpretation of the phænomena.

EXPLANATION OF THE PLATE (Tab. III.)

Fig. 1, 2, 3, 4. represent the tubes used in producing gaz from water by the interrupted electric discharges.

Fig. 5. represents the situation of the above tubes during the process of producing gaz from water.

Fig. 6, 7. represent the tubes employed in producing gaz from water by the first method, with uninterrupted electric discharges.

Fig. 8. shows the figure of the tube mounted with a brass funnel, used in the second method of producing gaz from water by uninterrupted electric discharges.

Fig. 9. represents the tube blown funnel-wise at the end, instead of being mounted with a brass funnel, as in fig. 8.

Fig. 8. represents the situation of the tubes fig. 8. and 9. during the process of producing gaz by the uninterrupted electric discharges.

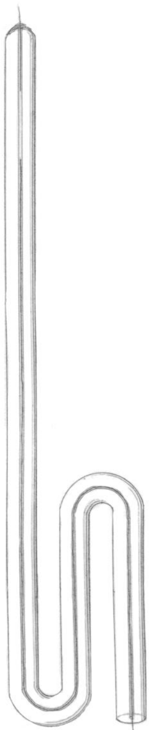


Fig. 1.

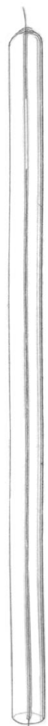


Fig. 2.

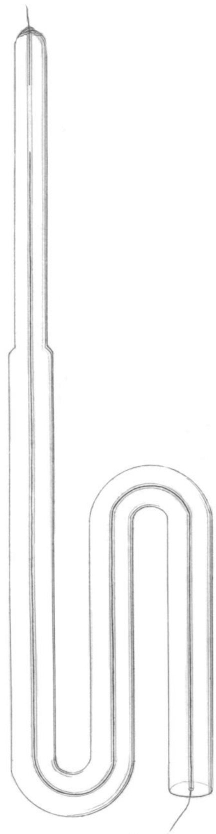
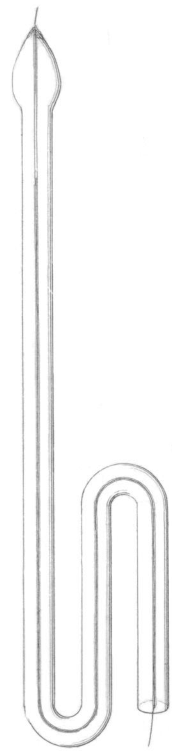


Fig. 3.



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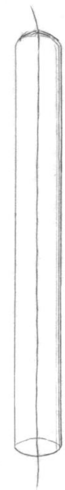

Fig. 6.

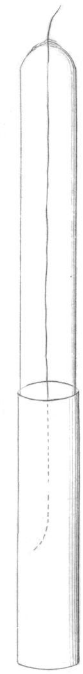

Fig. 7.

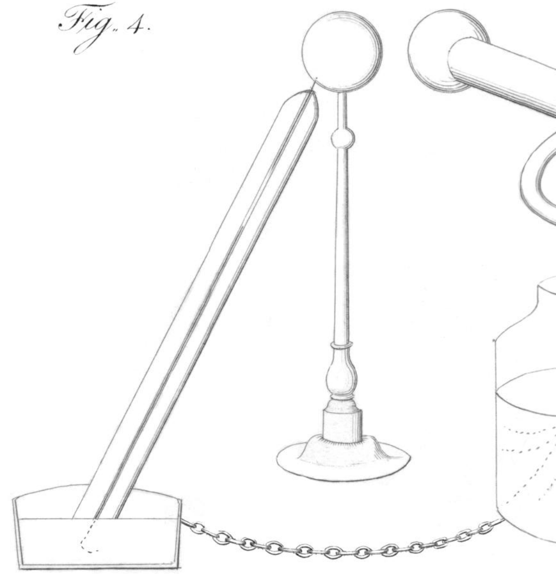

Fig. 5.

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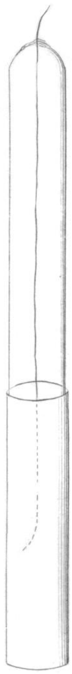

Fig. 7.

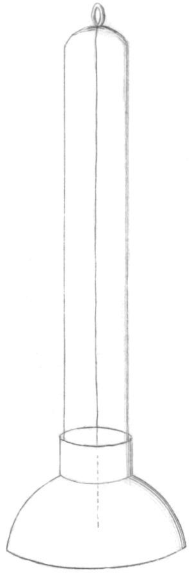

Fig. 8.

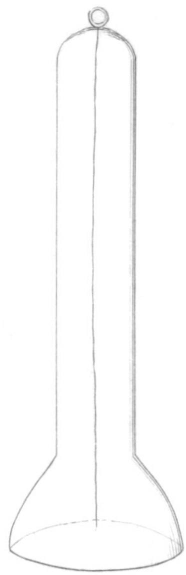

Fig. 9.

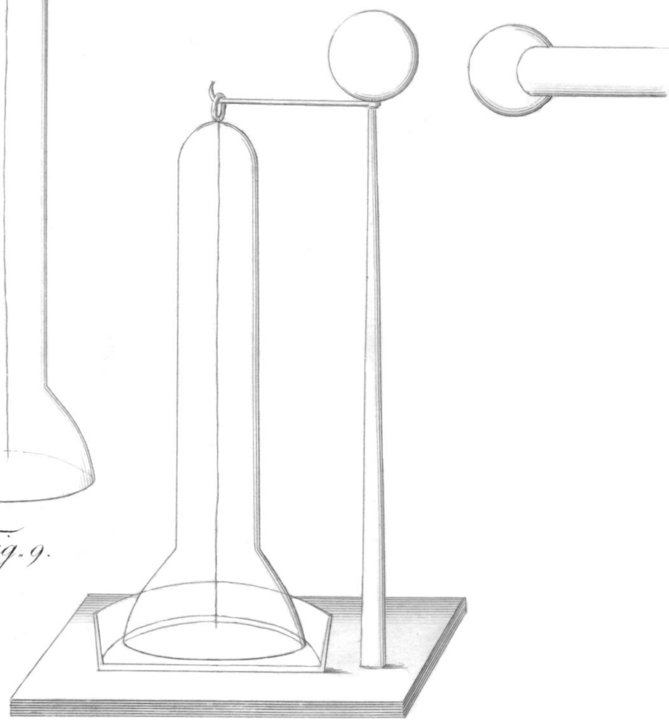

Fig. 10.

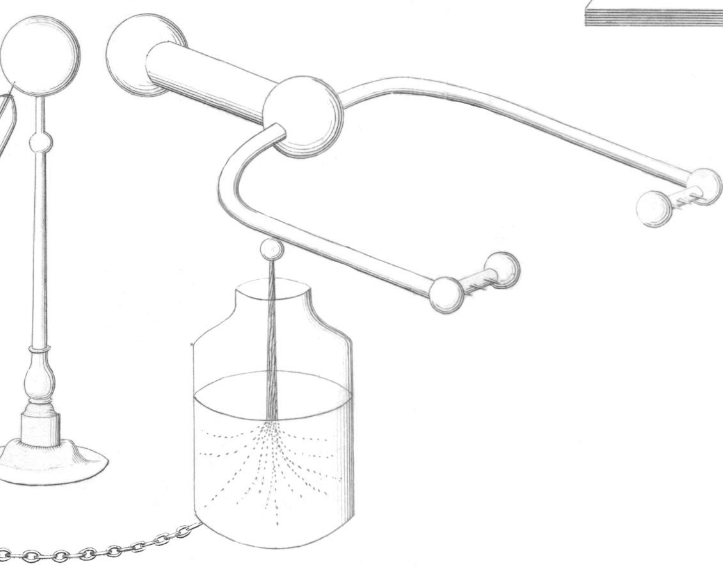

Fig. 5.

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